# FACSIMILE COMMUNICATION IN THE FLEET MARINE FORCE A "THIRD DIMENSION" IN TACTICAL COMMUNICATIONS

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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California


# THESIS

FACSIMILE COMMUNICATION IN THE FLEET MARINE FORCE A "THIRD DIMENSION" IN TACTICAL COMMUNICATIONS

by

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September 1975

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This paper introduces the reader to facsimile communication by defining in simple terms the general modus operandi of facsimile communication and then comparing the capabilities of record (teletypewriter) communication with facsimile communication. The present Department of Defense (DOD) communication system is predominantly a "two dimensional" system consisting of voice and alpha-numeric/special character record communications. The thesis discusses the inherent advantages of facsimile

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# Facsimile Communication in the Fleet Marine Force
# A
# "Third Dimension" in Tactical Communications

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ABSTRACT

This paper introduces the reader to facsimile communication by defining in simple terms the general modus operandi of facsimile communication and then comparing the capabilities of record (teletypewriter) communication with facsimile communication. The present Department of Defense (DOD) communication system is predominantly a "two dimensional" system consisting of voice and alpha-numeric/special character record communications. The thesis discusses the inherent advantages of facsimile communication along with the limitations of analog facsimile technology. The requirement for facsimile communication in the Marine Corps is discussed, noting that there is a requirement for this "third dimension" in tactical communications. A detailed discussion of recent digital facsimile technology is provided delineating the advantages of digital facsimile technology over existing analog facsimile equipment. Alternative facsimile applications in the Fleet Marine Force are outlined and a broad concept of digital facsimile employment is proposed. Conclusions based on the overall discussion are drawn, and recommendations in the form of steps that the Marine Corps should take toward implementation of a tactical digital facsimile system are provided.

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# I. INTRODUCTION

The purpose of this paper is to investigate the applicability of facsimile as a communication media within the Fleet Marine Force. Before any discussion of applicability can be pursued it is necessary to provide some basic background on facsimile communications. This background will enable the reader with a general communications knowledge to understand the concept of facsimile communications and have an appreciation for past and present facsimile applications. In order to complete the background requirement the thesis addresses current operational equipment and the most recent technology in the field of facsimile communications. This background enables the reader to better appreciate possible future applications of facsimile communication devices in the Fleet Marine Force (FMF).

With the necessary background to compare alternative applications of facsimile communication devices in the FMF, three employment options are discussed. This discussion is followed by a description of the existing record communication system in the FMF, explaining some of the problems and limitations associated with the present system. Finally, the author outlines a new concept of record communications for the FMF employing facsimile communication devices to both augment, and where desirable, replace existing teletypewriter

links. The advantages and disadvantages of the new concept are discussed, conclusions are drawn and recommendations are made outlining steps that should be taken toward implementation of facsimile communications in the FMF.

## II. BACKGROUND

### A. DEFINITION OF FACSIMILE COMMUNICATIONS

Stated simply, facsimile communication is a method of record communication whereby a document containing information in any format is transmitted over a communication media to a receiving terminal. Unlike teletypewriter transmissions that are restricted to alpha-numeric or special character formats, facsimile communication transmits any information that appears on the document being transmitted. Facsimile transmission is accomplished by scanning the document with a light source (photo-tube, laser beam, fiber optics, etc.) that registers relative blackness. As the document is scanned, signals produced are broken into thousands of tiny dots that are transmitted electrically. The strength of the signals vary with the relative blackness of the dot. For simple black and white documents only two signal states are required. For documents with gray shading, such as photographs, a range of signal strength states (depending on the number of gray shades desired) is required. Gray shading therefore requires more complex equipment.

The generated signals can be transmitted over various communication media. At the receiver the document is reassembled by a comparable facsimile device where the electrical signals recreated the original document dot by dot. Copy quality depends on the number of vertical lines scanned per page (usually expressed as lines per inch (lpi) and the number of

dot samples taken per horizontal line. The quality of the transmission media and the type of paper utilized for reception can also affect the quality of the received document. However, the quality (resolution) of the received document is primarily related to the number of lines scanned and dots per line transmitted. A simplified version of a facsimile system is shown in Figure 1.

A SIMPLIFIED FACSIMILE SYSTEM

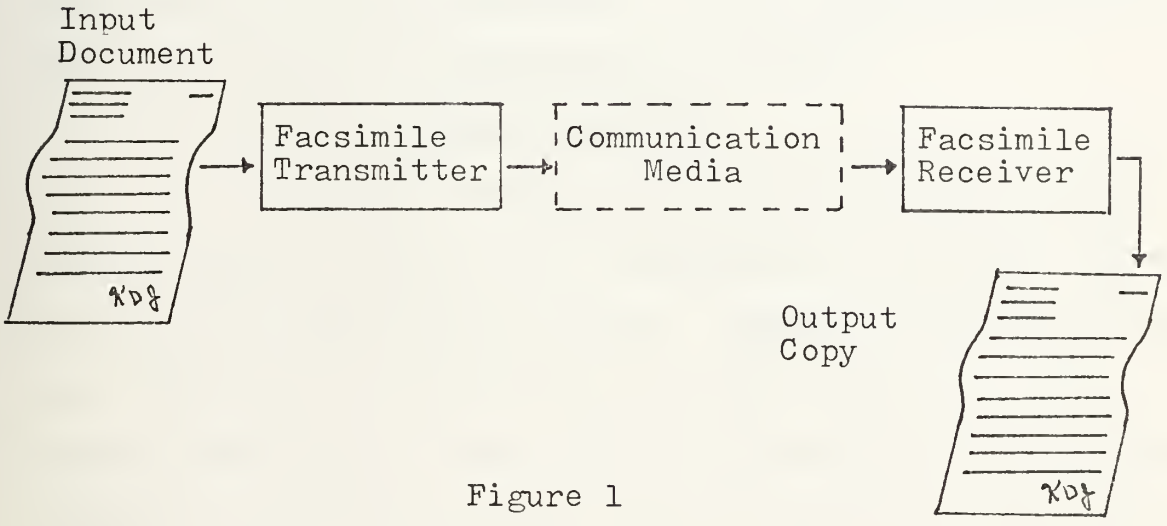



Figure 1

A more detailed description of facsimile devices and their operating characteristics are discussed in subsequent chapters.

## B. ADVANTAGES OF FACSIMILE COMMUNICATION.

In order to appreciate facsimile communication one must be aware of the inherent advantages of this method of communications. These advantages are listed in what the author considers to be a descending degree of utility to the users.

1. Unrestricted Format

Facsimile communication is not restricted to alpha-numeric/special character or black and white reproduction as are current teletypewriter machines. Information appearing on the document transmitted is scanned microscopically and transmitted regardless of its design or geometric shape [Ref. 1].

2. Minimal document preparation

A document to be transmitted over a facsimile system requires no special preparation. This results in two advantages over existing teletypewriter systems.

a. Faster message delivery

Without a preparation delay the time interval between message delivery for transmission and actual transmission is significantly reduced. Documents requiring immediate action can be transmitted on a near real-time basis. For higher level Marine Corps tactical organizations an appropriate example of how such savings could be effectively employed is the daily frag order.

> Up to four hours is now required to prepare the finished order for transmission. This time lag occurs in the manual punching of paper teletype tape and is in addition to the original typing of the order and the transmission time. With facsimile the preparation time could be virtually eliminated [Ref. 2].

It is recognized that Optical Character Reader (OCR) devices can also be used to eliminate message preparation

delays. However, the cost associated with current OCR terminal devices is much greater than for facsimile terminals, making OCR employment on a widespread basis infeasible from a cost standpoint [Ref. 1].

b. Elimination of human errors

The second advantage associated with not having to prepare a document for facsimile transmission is the fact that human errors induced in the preparation process are eliminated. The original message as approved and released by the originator is the transmission source document.

3. Minimal operator training

No special training is required to operate current facsimile equipment. During the field testing of an item of commercial facsimile equipment modified for the tactical environment it was found that operator training required less than one hour [Ref. 3]. In the commerical world facsimile operation is usually incidential to a person's primary duties [Ref. 4].

4. Capability over marginal transmission systems

Although facsimile requires more channel bandwidth to transmit an equivalent amount of alpha-numeric/special character teletypewriter information in the same time period, the facsimile process of micro-sampling does have one very important little known advantage. The advantage is that this micro scanning process allows the exchange of information over marginal transmission systems. Because the scanning

process samples only a small portion of the information to be transmitted at a time, the loss or change of a particular bit of scanned information will not significantly change the reconstructed information at the receiving terminal. For example, if a character is .1 inches high by .1 inches wide and the facsimile transmitting device scans at 100 lpi both vertically and horizontally, it will take 100 data samples (10 vertical lines by 10 horizontal lines) to reconstruct the original character. If a few data samples are lost or out of place the particular character will normally not be distorted beyond human recognition. Thus, even if communication line transmission errors exist, facsimile will not misspell a word, change a number, or the meaning of a sentence or diagram. However, teletypewriter transmissions are susceptible to the above vagaries.

5. Additional advantages

There are additional claims about the advantages of facsimile, however, the evidence is not conclusive. Two of these are:

a. Transmission media flexibility

Facsimile is more flexible over a variety of transmission media.

b. Mobile operation capability

Facsimile can operate better in a mobile configuration than the teletypewriter.

One OPNAV staff section stressed increased emphasis on facsimile communication R&D stating that:

> A picture or graphic, directly assimilated by the human eye-mind system, is less abstract than either the written word or the sounded word, and thus is more efficient in rapidly transferring information for human comprehension [Ref. 5].

C. BRIEF SUMMARY OF PAST FACSIMILE UTILIZATION

Although facsimile communication has been employed for many years, it has not received the attention afforded to the other forms of communication media, namely the voice and teletypewriter (record) systems. It has only been over the last ten years or so that facsimile communication has received considerable attention. Yet,

> Long distance facsimile is not a new technology. The first commercial transatlantic radio facsimile service for news photos, for instance, was inaugurated in 1926 [Ref. 6].

Facsimile communication is certainly not a new technological development. It has been operational as long as teletypewriter operations. During World War II over one-hundred "Hell German Facsimile" machines were built for use by the Signal Corps to aid in breaking German coded transmissions [Ref. 7]. The first real indication of an interest by the Marine Corps in facsimile communication that this researcher could uncover was in the form of a staff study done by Colonel Kenneth B. Boyd (A previous director of the Communication Officers School in Quantico, Va.) while attending the Senior Officers Course as a Major, which is equivalent to today's Command and Staff

College, as a student in 1955. Colonel Boyd's staff study sought to determine if facsimile communications could be utilized in the Marine Corps. The result of his research effort was the conclusion that facsimile should be adopted for Marine Corps use [Ref. 8].

## D. CURRENT EMPLOYMENT OF FACSIMILE IN COMMERCIAL WORLD

The predominant use of facsimile has been by the civilian community for commerical purposes. The newspapers have employed facsimile transmission for many years to relay news photos and other non alpha-numeric information to distant printing distribution points. Today the Wall Street Journal uses facsimile to transmit a duplicate of the entire daily San Francisco edition to Los Angeles. The entire newspaper is transmitted at 1000 lpi over a wideband television size communication channel [Ref. 9]. Facsimile has also been effectively employed in the law enforcement area, primarily for suspect identification. In recent years many new fixed and portable facsimile transceivers have been manufactured. The portable facsimile sets are lightweight (about the size and weight of a portable electric typewriter) and simple to operate. No special training is required and they can be utilized over existing public switched telephone systems. With this capability the average businessman only needs access to a telephone to transmit a standard size page of record copy in any format. The portable facsimile transceivers are normally equipped with simple telephone-to-facsimile acoustical

coupler devices that only require placing the telephone handset in a cradle device to establish the system signal path. With this simple acoustical connection that employs technology that has been available for many years, the new lightweight portable facsimile transceivers have provided the commercial world with a real-time unrestricted format record capability.

> The use of the telephone network to carry acoustically coupled signals from facsimile machines began in earnest in 1968, about two years after MAGNAVOX developed the first acoustically coupled facsimile machine, the MAGNAFAX 840, for business office applications [Ref. 4].

In looking at possible applications for facsimile in the Army, MASSTER (Modern Army Selected Systems Test, Evaluation and Review) pointed out that:

> The technological development of commercial facsimile sets has advanced greatly in recent years as industry has found more need to transmit copies of documents rapidly over long distances [Ref. 10].

Another research source indicated that:

> Facsimile systems which transmit pictures, maps, and diagrams are growing increasingly important as communication tools for business [Ref. 11].

The U. S. Postal Service also recognizes the potential of facsimile communications as a means of improving service and is currently embarked on an ambitious research program that is exploring the advantages of an electronic mail system using facsimile communication devices [Ref. 9]. One estimate of the anticipated growth of commercial facsimile machines predicted a growth from about the 100,000 facsimile

machines in use today throughout the world to a total of about 300,000 units in operation by 1980 [Ref. 6]. The growth of facsimile communication devices has been, and is expected to continue, at an exponental rate. This growth can be attributed to the fact that facsimile communication in the commercial world is satisfying a growing requirement for the inexpensive transmission of record information in any format on a real-time (or near real-time) basis.

## E. PREVIOUS MILITARY EMPLOYMENT OF FACSIMILE

Facsimile has been used by the military for many years for limited applications. In the Navy and Airforce facsimile is utilized primarily for the distribution of weather information. Although these facsimile terminals are located worldwide, their utilization has been limited almost entirely to the exchange of weather data. During the Vietnam conflict a special high resolution facsimile link was established between Vietnam and the United States to transmit reconnaissance photos via satellite [Ref. 12]. Recently, the Navy utilized a XEROX Telecopier over the Navy Operational Radio Telephone Service (NORATS) to send and receive pictures from the USS Guadalcanal while running sea tests on the CL-84, a tilt wing V/STOL aircraft. In comments made after the tests were completed, it was said that:

> ...This application of the XEROX Telecopier contributed greatly to the successful termination of the CL-84 tests and may possibly play an important role in the future of ship-to-shore telecommunications [Ref. 13].

In the latter sixties and early seventies the U. S. Marine Corps expended considerable effort developing a military version of the MAGNAFAX 850 copier produced by MAGNAVOX Corporation. The military version was given the nomenclature AN/GXC-7. The AN/GXC-7 appeared to have a lot of application potential and a limited number of test models were produced with internal components designed to withstand the rigors of the tactical environment. However, during field testing the AN/GXC-7 was found to be inadequate and it was never purchased in any quantity [Ref. 3]. The military services have been involved with facsimile communications for many years, but have only utilized facsimile for special requirements. No application for facsimile as a general communication tool has been established. Although there are numerous instances today where higher levels of the DOD community are utilizing the new commercial facsimile machines to carry on their daily business, thus far there has been no broad utilization of facsimile for the exchange of general tactical information. It is this aspect that the remainder of the thesis addresses.

## F. MARINE CORPS REQUIREMENT FOR FACSIMILE COMMUNICATION

In the Marine Corps a Specific Operational Requirement (SOR) CC-8.1 was promulgated that states a requirement for transmitting and receiving facsimile [Ref. 14]. The SOR specifies that there is a need to electronically exchange the information contained on the following types of documents:

1. Overlays and sketches
2. Hand or typewritten copy
3. Charts or forms
4. Photographs

A draft Required Operational Capability (ROC) is presently being staffed for a tactical facsimile set (TFS). When promulgated the new ROC will supercede the original SOR [Ref. 15].

In addition to the Marine Corps,

> The U. S. Army recognizes that reliable facsimile equipment could replace some existing teletype systems and notes that the present record copy portion of the division communication system is composed of antiquated and expensive equipment requiring highly trained operator and maintenance personnel [Ref. 16].

Both the Army and the Marine Corps are utilizing outdated and unreliable teletypewriter equipment as the primary means of exchanging record communications between tactical units. Existing teletypewriter systems require that error free outgoing messages be prepared in punched paper tape format prior to transmission. In today's rapidly changing tactical environments such delay would appear to be unacceptable. Although field testing found the AN/GXC-7 unsatisfactory, the same report that stated the equipment was unsatisfactory went on to recommend that the U. S. Marine Corps continue development efforts to field a facsimile for practical utility in the field [Ref. 3].

While attending Command & Staff College in Quantico, Va. in 1969-70 the author interviewed Lt. Col. M. E. Irons, an experienced Marine communicator and instructor of communications at the Command & Staff College. The purpose of the interview was to identify requirements for facsimile communication in the Fleet Marine Force. Lt. Col. Irons had served as a regimental communications officer during the Vietnam conflict. One particular incident cited by Lt. Col. Irons recounted the recovery of some intelligence documents written in Asian characters. The battalion level unit that recovered the documents did so during a period of very bad weather, and the documents could not be flown back to higher headquarters for interpretation. It was subsequently determined that the information pin-pointed a large enemy headquarters, but because of the delay in receiving the information at higher headquarters where it could be interpreted, the eventual action taken was ineffective [Ref. 17]. If a facsimile communication system had been available the documents could have been transmitted to higher headquarters with little delay, since facsimile communication terminals are fluent in all languages.

> This ability produces an exact duplicate of whatever is placed in the machine, and in so doing eliminates any language barriers. For example, many languages, such as Japanese, Arabic, Chinese, Hebrew and Russian have totally different alphabets that would require special keyboards to transmit teletype messages. With the facsimile, the message is received exactly as it is written [Ref. 10].

Examples of the types of tactical information particularly suitable for facsimile transmission are contained in Appendix A. There is a definite requirement for facsimile communication in the tactical environment. Why has there not been a greater employment of facsimile communication devices in the tactical arena? To answer this, one must look at the limitations of past facsimile equipment.

## G. LIMITATIONS OF ANALOG FACSIMILE EQUIPMENT

Facsimile equipment in use today is predominantly of the analog varity. An analog transmission consists of a continuously varying signal. The information transmitted varies on a continuous basis as compared with digital transmissions which are composed of discrete separate pulses or signal levels [Ref. 18]. One of the serious limitations of analog facsimile is the fact that there have been no standard crypto devices in the Department of Defense (DOD) inventory that will encrypt the normal narrowband (35-3500 HZ) analog voice telephone channel. Thus, when utilized over multichannel radio circuits, analog facsimile information is exchanged in the clear. In a tactical environment denial of information to the enemy is a prime consideration. A recent DOD effort to provide security for narrowband High Frequency (HF) radio circuits has been the development of an analog compatible cryptographic device called PARKHILL. This device could be utilized over narrowband multichannel circuits, but such employment is unlikely since the device is considered an

interim cryptographic measure and procurement is expected to be limited to quantities for use over critical HF nets.

During field testing of the AN/GXC-7 it was determined that:

> Due to the limited availability of FM frequencies and other considerations it was deemed a requirement that multichannel radio circuits would be the most appropriate media by which to exchange facsimile transmissions. It was found that facsimile exchange via multichannel radio was feasible and at times very good [Ref. 3].

However, the tests were limited to unencrypted transmissions. In addition to the above limitation, the following were also noted as deficiencies of the AN/GXC-7:

1. Insufficient reliability.
2. Excessive weight.
3. Inability to operate 24 VDC.
4. Lack of adequate over-voltage/current protection.
5. Limited reproduction capability of the received copy.
6. Excessive transmission time (6 min/standard page).

It should be mentioned at this time that although the AN/GXC-7 was cited with the above limitations, one command in the evaluation chain noted that:

> ...many of the shortcomings cited were in fact specified as required characteristics in the Specific Operational Requirement [Ref. 2].

In other words, the equipment satisfied SOR requirements, but the SOR specifications did not reflect the actual needs of the tactical users. The final report on the AN/GXC-7 [Ref. 3] submitted to Headquarters Marine Corps by the Marine Corps

Development and Education Command (MCDEC) came to the following conclusions:

1. The concept of tactical information exchange via facsimile is feasible.

2. The AN/GXC-7 had basic capability limitations that rendered it unsuitable for tactical Marine Corps use.

With this brief summary of the advantages, history, and limitations of analog facsimile communication as background, existing and anticipated facsimile technology can now be addressed.

## III. CURRENT FACSIMILE TECHNOLOGY

As mentioned earlier facsimile communication has experienced a significant increase in interest during the last few years because of its near real-time capability to exchange graphic information of any format over voice grade public switched telephone systems. In 1966 MAGNAVOX developed the first commercially available acoustically coupled facsimile machine for use over the switched telephone network [Ref. 4]. Since that time several companies have developed and marketed facsimile terminal equipment. Speeds of transmission for analog machines have gradually dropped from six minutes per page to three minutes per page [Ref. 19]. However, analog technology appears to be limited to the three minute barrier in order to provide adequate copy quality. The three minute per page analog units provide the minimum in acceptable black and white copy quality and are more liable to distortions caused by line interferences than their six minute per page counterparts [Ref. 1]. Faster analog transmission speeds require an unacceptable degradation in copy quality (resolution). Although today's analog technology has proven more than acceptable in the commercial world, the unique requirements of the military can only be partially satisfied with current analog facsimile equipment. However, rapidly emerging from the development stage is a new method of facsimile transmission that employs digital technology.

It is common knowledge that the future direction of the DOD communication system is digital. One goal of the DOD sponsored Joint Tactical Communications (TRI-TAC) Program is to effect a transition from today's analog communication system for tactical forces of the Services to an all digital system [Ref. 20]. The primary reasons for the transition to an all digital communication system are overall system interoperability, increased information throughput capability, and the relative ease with which a digital signal can be encrypted in comparison to an analog signal. It is no longer a question of: should the DOD go digital? It is only a question of: when can the digital switchover be accomplished? With DOD's huge inventory of analog equipment a rapid transition to an all digital system is unlikely because of the cost involved. However, as analog equipment slowly phases out of the system it will be replaced by digital equipment. Current DOD plans are to field a tactical hybrid analog/digital switch before the 1980's [Ref. 21]. With the fielding of this equipment the transition will begin in earnest.

The switch (AN/TTC-39) is being developed by the Army under the auspices of the TRI-TAC Program. The switch will provide both a circuit switching and message switching capability.

> The AN/TTC-39 (Central Office, Communication, Automatic) is a family of hybrid, analog/digital, automatic, transportable tactical switching equipments. These switches will provide automatic circuit switching service for analog and digital traffic, with store-and-forward switching for message traffic provided by an add-on module [Ref. 20].

In conjunction with the AN/TTC-39 development will be the development of many ancillary tactical digital communication devices designed for use by all components of the DOD. All of the Services are participating in the development of the various ancillary terminal, transmission, and lower level switching equipment.

It is clear that DOD is moving to an all digital communication system. A discussion of the advantages of digital over analog facsimile communications is now in order. The inherent advantages of a facsimile transmission over a teletypewriter transmission have already been discussed. During the comparison of digital and analog facsimile the reader might keep in mind previously discussed limitations that rendered analog technology unsuitable for tactical applications. With these in mind the reader can better appreciate the potential of digital facsimile in the tactical environment.

> The potential of facsimile will be more fully realized with the use of digital data compression and digital transmission, which constitute a more efficient method of handling facsimile than by analog transmission [Ref. 6].

In order to discuss digital facsimile in a logical manner a brief description of digital facsimile in general is appropriate. After this introduction the following topics are discussed: Security, Speed, Resolution quality, Reliability, Flexability/Compatibility, and Cost.

A. DIGITAL FACSIMILE

As in analog facsimile systems, a document scanning process is also employed in digital facsimile transmission systems.

> A scanning device picks up light reflected off the original document. The signal from the scanning detector is converted into a digital bit stream. The bit stream is then introduced into compression circuitry where a code is applied to reduce the number of bits necessary to convey the scanned information. The output of the compression is directed to the transmit section of a modem where it is changed into a modulated carrier for transmission over a conventional telephone channel [Ref. 1].

At the receive terminal the reverse process occurs and the compressed data from the digital output of the receiving modem is reconstructed to its original bit stream and fed into a printing mechanism. A diagram of the functional elements of a digital facsimile terminal is provided in Figure 2.

DIGITAL FAX TERMINAL (FUNCTIONAL ELEMENTS)

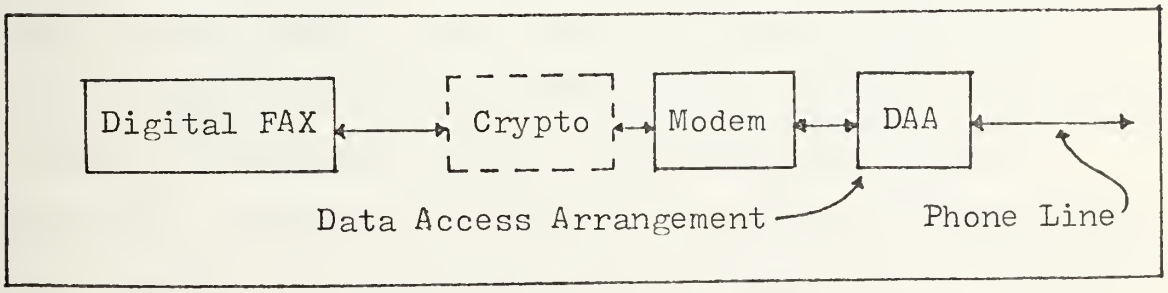



FIGURE 2

Three basic technological developments in recent years have contributed significantly to the emergence of digital facsimile [Ref. 1]. These are:

1. The miniaturization and fabrication of electronic components employing Large Scale Integration (LSI) and Metal Oxide Semi-conductors (MOS).

2. The development and practical implementation of extremely efficient data compression algorithms.

3. The development of high speed modulation/demodulation devices (modems) capable of operating at low error rates over switched nonconditioned voice grade lines.

In Figure 2 the signal generated by the digital facsimile transmission equipment is a direct current digital bit stream which is fed into the crypto equipment. The encrypted digital signal is then fed into a device called a "modem" or modulator/demodulator. The modem is required in order to transmit the signal pulses over long distance voice grade communication channels. The digital data pulses fed into a modem modulate the transmission carrier signal in such a manner that the integrity of each data bit is effectively carried over the voice grade channel. The number of data bits per second that can be transmitted over a communication channel is directly related to two basic factors. The bandwidth (range of frequency responses that can pass through the channel) and the quality of the line (amount of attenuation in decibels per unit length and signal delay across the frequency bandwidth as the signal travels through the channel).

The last item in Figure 2 that requires explanation is the Data Access Arrangement (DAA). The DAA is required to provide DC isolation between the modem and the communication

channel. The DAA prevents the data sent out by the modem from overloading switched telephone lines, from introducing excessive transient signal levels, and from interfering with any of the switching supervisory control signals such as dial or off-hook tones.

B. SECURITY

An inherent capability of any digital signal is the ease with which the bit stream can be encrypted. As was mentioned previously, in addition to the ability of a digital communications link to provide greater information throughput than an analog communication link of eqivalent bandwidth, one of the forces driving the DOD move to an all digital system is the communication security consideration. A digital facsimile signal will be fully compatible with existing and projected digital encryption devices.

> Because the output of the new facsimile systems are digital in format, they suffer no degradation whatsoever when processed through standard government furnished encryption equipment. In addition, problems of interface, synchronization and signal 'handshake' are minimized because both the facsimile and crypto equipment are of the same character [Ref. 1].

C. SPEED

> The combined effect of data compression and high speed modem technology substantially reduces transmission time. For standard transmission of a new digital facsimile, a 250 word typewritten message can be transmitted in less than one minute. This is a 600% improvement over the typical analog facsimile in use today [Ref. 1].

If the previously discussed six minute per page analog facsimile was considered valuable for transmitting a frag order, the value of future digital facsimile devices would appear to be proportionately greater. This increase in speed significantly enhances the possibility of real-time facsimile applications. For example, while previously a ten page plan or report would have required one hour of transmission time, a digital compression facsimile system would take less than ten minutes. The JCS J-6 staff recently received an unsolicited proposal suggesting a project that would provide digital facsimile systems capable of transmitting four to six times as much data over 3 KHz channels as ordinary analog facsimile [Ref. 22].

The purpose of digital data compression is, as the name implies, to compress the intelligence to be conveyed to the distant terminal into a minimum number of electronic signals that actually require transmission over the communication medium. Data compression algorithms are used to greatly reduce the signals required for the transmission of redundant data. An example of such signal redundance would be the signals generated when scanning a blank (all white) area of the document to be transmitted. The data compression algorithm codes the stream of equivalent bits in such a manner that only a few transmitted bits represent the original long stream of like bits. This reduces the number of actual transmission bits required to convey the information to the receiving facsimile terminal. There are various algorithms employed

for data compression and some provide greater data compression than others. However, data compression ratios of five to one are common. This means that, on the average, five bits of scanned data on a black and white document of average information density can be compressed into a single bit. Therefore, only one fifth of the original quantity of data bits generated when scanning the document need to be transmitted over the communication medium. Using a hypothetical example it can be seen that a document with 1,000,000 bits of data could be reduced to 200,000 bits of compressed data for transmission purposes. Thus, only one fifth of the transmission time is required when data compression techniques are employed. With the small buffer storage devices, now available from LSI/MOS technology, as an integral component of modern digital facsimile devices, the 200,000 bits of compressed data can be sent to the modem (via the crypto device if encryption is required) at whatever bit rate the modem is designed to accomodate. A good example of this technology is the compression/reconstructor printed circuit board (DFC-20) used for the Dacom Corporation digital facsimile terminals. A picture of this technology is provided in Appendix F. In the case of the DFC-20, LSI/MOS technology has reduced the equivalent of 30,000 transistors to a printed circuit board weighing less than one pound and measuring only about 10 by 18 inches [Ref. 23].

To accomplish the interface between the variable data rate generated by the digital facsimile scanning/data compression process and the data rate of the modem a LSI/MOS digital buffer is utilized. The compressed data output of the compression process is fed into the buffer. At the same time compressed data is fed into the buffer, the buffer also sends data to the modem. The rate at which data is read out of the buffer memory is controlled by the clock rate of the external modem. For example, if the modem is operating at 2400 bits per second (bps), the buffer would be told to read data into the modem at this rate. Various controls are designed into the computer logic to insure that data read into the buffer does not exceed the storage capability of the buffer. If this should occur the document scanning and read in process is temporarily halted until sufficient data storage is again available in the buffer [Ref. 24]. One significant advantage of variable bit rate channels is the capability of adjusting the transmission speed to the available channel bandwidth and/or quality.

> If a terminal (digital facsimile) is required to operate over a narrowband or low quality channel, the clock rate can be reduced so that the equipment operates at a transmission rate sufficient to communicate without excessive error [Ref. 1].

In conjunction with the development of data compression schemes, there have also been important advances in modem technology. In the past modems have been limited to a bit rate of about 1200 bps over unconditioned voice grade communication channels. To increase this bit rate conditioned lines

were required. A conditioned line has uniform (linear) signal attenuation and low distortion due to equalization of signal delay across the entire channel frequency range. The degree of line conditioning is dependent on the relative amount of signal attenuation and delay that exists on the line. A properly conditioned line has very little attenuation and delay. Such line conditioning requires special equipment and dedicated circuits so that the channel path always remains the same. This is not possible when digital facsimile devices are operated over switched networks where the signal path (and therefore line characteristics) can vary for each call. Although it is not possible to condition switched circuits, recent modem developments make allowances for variable attenuation and distortion on the voice channel by compensating through automatic equalization within the modem itself. Although internal modem equalization makes no actual electronic improvement of the circuit, it compensates for line deficiencies with automatic level adjustments at the terminal ends. Thus, unconditioned switched circuit paths appear to be conditioned as far as the modem is concerned, and are therefore suitable for passing bit rates much higher than the previous 1200 bps for unconditioned lines. Dacom, Inc., a digital facsimile manufacturer has recently marketed a digital facsimile (Model 412 Securefax) with a modem capable of passing 2400 or 4800 bps over voice grade unconditioned lines. With such high bit rates, acoustical coupling no longer provides a satisfactory terminal to transmission media signal path and a hard-wire connection is required [Ref. 23]. This hard-wire

connection is easily accomplished with commercial telephone systems. For tactical applications field telephones are normally equipped with an external electrical plug connector, making connection simply a plug-in and operate process. Through the employment of LSI/MOS technology the Dacom modem weighs only 30 pounds and has dimensions of 5.5 by 19 by 19.5 inches. The 412 Securefax is compatible with existing National Security Agency COMSEC equipment [Ref. 25]. A picture of the printed circuit card for the basic modem electronics is shown in Appendix F. This card also weighs less than a pound and measures 6 by 8 inches [Ref. 23].

The combined advantages of data compression and higher modem bit rates over unconditioned circuits has resulted in a dramatic reduction in digital facsimile transmission time over voice grade switched communication lines. This improved capability can readily be seen in the advertised specifications for the 412 Securefax shown in Table 1 below [Ref. 25]. The transmit times given are for a standard page (8.5 by 11 inches) sent over unconditioned lines with a 4800 bps modem.

VARIOUS RESOLUTION TRANSMIT TIMES
FOR THE DACOM 412 DIGITAL FACSIMILE TERMINAL

| Vertical Resolution | Horizontal Resolution | Speed |
|---|---|---|
| 67 LPI | 200 LPI | 35-45 SEC |
| 100 | 200 | 50-60 |
| 200 | 200 | 90-120 |

TABLE I

D. RESOLUTION

> One of the most useful benefits of digital data compression, in addition to speed, is its ability to provide increased resolution with minimum time or bandwidth penalty [Ref. 1]

As mentioned earlier, copy quality depends on the number of lines scanned (usually expressed as lines per inch (lpi)) and the number of samples taken per line. When viewed as a horizontal and vertical scanning matrix, each matrix location represents a dot sample. In analog systems where data compression techniques cannot be used, an increase in resolution from 100 lpi to 200 lpi (vertical and horizontal) requires a corresponding directly proportional fourfold increase in transmission time because the scan matrix for one square inch has increased from 10,000 (100 X 100) to 40,000 (200 X 200) dots. However, digital data compression systems do not increase transmission time in the same direct proportion as analog facsimile systems. For technical reasons which go beyond the scope of this paper and the technical background of the author, the same resolution increase of 100 lpi to 200 lpi on a digital data compression facsimile device results in only about a twofold increase in transmission time instead of the fourfold increase required in the analog system. This characteristic of digital data compression partically overcomes the time penalty previously imposed when transmission of fine detail was desired [Ref. 1]. It appears possible that a 400 lpi (along the horizontal scan axis) facsimile transmission will be possible in the near

future without a significant increase in the number of bits actually transmitted over the communication channel. This increased capability is simply based on greater compression ratio technology. Dacom, Inc. is under contract with the California Crime Technology Research Foundation to develop this capability for fingerprint transmission requirements [Ref. 23].

The performance specification for the Lightweight Tactical Digital Facsimile (TDF) presently being developed by the Navy under the auspices of the TRI-TAC program calls for operator selectable resolutions of 100, 150 and 200 lines per inch with gray scale modes of 2, 4, 8, 16 or 32 gray shades [Ref. 26]. Each of the modes consists of high contrast black and white at the scale limits with the appropriate intermediate gray shades. In other words, scale mode number one would be simply high contrast black and white without any intermediate gray shading levels. Scale mode number five would be high contrast black and white with 30 intermediate shades of gray. The resolution specifications above should be more than adequate for almost all tactical military applications. At the 1974 Institute for Graphic Communications Conference, during the discussion of photofacsimile recorders, a 100 lpi photograph recording with good gray scale correction was considered adequate for the normal viewing distance of 14 inches. It was further stated that it would be unlikely that the viewer would realize it was a facsimile without carefully studying the document [Ref. 9]. Even without gray scale shading, modern

digital facsimile transceivers operating at 200 lines per inch are capable of satisfying the most detailed alpha-numeric and graphic document requirements. Modern digital facsimile machines can exchange information barely discernible to the human eye. A 200 lpi resolution is suitable for transmitting fingerprints where the width of the ridges and valleys can be as small as five thousandths of an inch. The Dacom Model 412 Securefax, presently available commercially, will transmit an average density 8.5 by 11 inch page document at 200 lpi over voice grade circuits in 1.5 to 2 minutes. In the Phase II design plan for the TDF the contractor made the following statement about the product under development.

> The datalog laser receiver has the capability of receiving, correctly interpreting, and producing hardcopy readouts of a data digitally-encoded by the TDF transmitter representing graphics ranging in resolution from 96 to 192 lpi and 32 shades of gray. The receiver is designed to interface with existing modems and comsec equipment at digital rates up to 32 K bits/sec [Ref. 27].

The technology for satisfying the TDF performance specifications certainly appears to be available. The goals of the TDF SOR and the TRI-TAC Performance Specification are considered attainable in the technical development plan [Ref. 28]. The TDF operational/performance characteristics are listed in Appendix B.

## E. RELIABILITY

The future digital facsimile equipment will contain a minimum of mechanical parts and will be composed of electronic components of LSI/MOS circuitry. The scanning will in all

probability be done with laser beam light sources [Ref. 27]. Such components are very reliable and should be able to satisfy the durability required for military use. The specifications for the Tactical Digital Facsimile (TDF) call for a Mean Time Between Failure (MTBF) of 2500 hours and a Mean Time To Repair (MTTR) of 30 minutes [Ref. 16].

F. FLEXIBILITY/COMPATIBILITY

Digital facsimile would appear to have greater flexibility/compatibility than analog facsimile for the following reasons:

1. Compatibility with other digital equipment and systems.

> The output of a digital facsimile may be stored on any of the media upon which computer output is stored. This includes magnetic tape, disc, or solid state memory. With compression the efficiency of storage increases in proportion to the compression ratio [Ref. 1].

This means that digital facsimile would be completely compatible with the computer controlled message switching system planned for the AN/TTC-39 switch. Digital facsimile's compatibility with digital COMSEC devices has already been discussed. The DOD is also utilizing satellites to a much greater extent for long haul transmissions. Digital facsimile would appear to be compatible with future satellite systems. Communications Satellite Corporation recently announced a new satellite service to be provided for the growing population of facsimile users.

> A new digital Single-Channel-Per-Carrier (SCPC) satellite transmission system is being introduced. This system demonstrates the advantages of digital service. A typical

> high speed facsimile user who operates at 48 Kbps presently requires a 'wideband' 48 KHz channel, which is 12 normal analog voice channels wide. One digital SCPC 4 KHz voice size channel, however, is capable of carrying 56 Kbps, which easily includes the complete wideband data stream [Ref. 6].

One of the advantages of digital facsimile is its compatibility with any other digital communication system. In reference to the new "one minute" digital facsimile devices one author stated that:

> Some one-minute FAX machines will accept a message header, probably a prepared card that the machine will read first to 'seize' the receiving FAX machine. Then the message will proceed through the digital data communications network just as if it were a message sent through a conventional data terminal [Ref. 4].

The Defense Communication Agency (DCA) has been exploring the use of facsimile over the AUTODIN system. This application of facsimile communication was recently demonstrated by DCA with the transmission of digital facsimile over the AUTODIN system.

> AUTODIN, a worldwide, digital store-and-forward communication network, was designed specifically for the transmission of alpha-numeric information. Inherent in its design, is the capability to transmit any digital information, as long as it is formated in a manner similiar to alpha-numeric messages. It was this inherent capability which permitted development of the concept of facsimile transmission via AUTODIN [Ref. 29].

During experimentation with facsimile transmissions over AUTODIN, it was determined that the average 9 by 11 inch document could be transmitted within one AUTODIN message of 500 blocks, if a resolution of 100 lpi were used. For very

complex documents and/or gray-scale shades where data compression will not significantly reduce the number of bits actually transmitted, more than one AUTODIN message was required for a complete transmission.

> On 26, 27 and 28 September, 1972, the Facsimile-Via-AUTODIN capability was successfully demonstrated at DCA headquarters in Arlington, Va. [Ref. 29].

The tests DCA conducted established the fact that digital facsimile is compatible with the worldwide digital AUTODIN transmission system. A wide application of facsimile communication in the DOD would significantly increase the data throughput requirement of the AUTODIN system, however, the AUTODIN system has proven to be extremely efficient and was designed with expansion in mind. AUTODIN is presently operating at 50% or less capacity world-wide. For those instances where only a graphic representation will adequately convey the intended meaning, digital facsimile transmitted through the AUTODIN system would be invaluable.

2. Compatibility over varying bandwidths.

Digital facsimile can operate without modification over varying bandwidths. Digital facsimile has been operated by the U. S. Navy over HF radio links at bit rates as low as 75 bits per second. No degradation of copy quality occured even at these low narrowband transmission rates [Ref. 1]. The only requirement when operating digital facsimile over various bandwidth channels is that the digital output must be syncronized with the clock rate of the associated digital modem.

3. Compatible with digital and analog networks.

Digital facsimile can operate over both digital and analog networks. Over analog communication networks a modem is required. However, the ultimate goal of DOD communications is a 100% tactical digital transmission system [Ref. 20]. If this comes about, digital facsimile at multiple data speeds will be fully compatible with buffered digital transmission systems and modems will not be required.

4. Low Radio Frequency (RF) emissions.

A little mentioned advantage of digital facsimile worth noting is the level of unwanted RF emissions generated.

> In the area of meeting government standards for radio frequency emission, digital circuitry, and LSI 'chips' have a real advantage. The low voltages utilized have inherent low radiation characteristics. If solid state or quasi-solid state scanning and printing devices are used, then the radiation problems are further minimized. Under ideal circumstances no external shielding would be required to meet federal standards for secure operation. One of the severest problems has thus been set aside if the equipment can be made to meet federal standards with relative ease [Ref. 1].

5. Miscellaneous advantages.

In addition to the above, digital facsimile is compatible with computer controlled store-and-forward devices, switching systems, polling, broadcast routines, error detection and correction, and self-checking techniques.

G. COST

Any discussion of available technology must be placed in the context of cost to the user. An item of communication equipment can be designed to satisfy the most complex requirements, but if the item is too costly, it will never be procured for system-wide implementation. It appears that digital facsimile devices can be acquired at reasonable cost levels. The Dacom 412 Securefax, facsimile transceiver (less modem), can be purchased for $14,130 as listed in a July 1974 GSA approved catalog [Ref. 30]. In discussions with Mr. Meltzer of Dacom Corporation he felt that if purchased in sufficient quantity, a digital facsimile terminal similar to the capability of the Dacom 412 (including modem) could be produced for about $10,000 per item [Ref. 23]. Dacom is presently working on a redesigned (but not MIL SPEC) version of the 412 for military applications that will be approximately 10 cubic feet and weigh about 200 pounds [Ref. 31]. In discussions with Mr. Beebe of the Naval Electronics System Command on the cost of the TDF terminal, he stated that the design-to-cost estimate for the TDF if $11,000 per copy. Mr. Beebe felt that this cost estimate would be achieved because he believed reasonable escalation factors were taken into consideration in arriving at the estimate [Ref. 32].

The previous discussion provided the reader with a general background on facsimile communications and an introduction to digital facsimile technology that has recently become available. Digital facsimile can provide not only

a "third dimension" in tactical communications, but possibly an improved record communications capability. The question that must now be addressed is: How can this new communication capability be most effectively employed by the tactical forces of the Marine Corps?

## IV. EXISTING FLEET MARINE FORCE COMMUNICATIONS

Before discussing alternative ways of employing digital facsimile in the FMF, a brief description of the present tactical communications system is in order. The system can be considered "two dimensional" since only voice and alpha-numeric/special character teletypewriter signals are carried over the available communication media. In the Marine Corps, as in most large military and civilian organizations, information flows up and down hierarchical levels of command. Although there are many different organizations in the Marine Corps, the basic fighting unit organized for self-sustained operation is the infantry battalion. All other Marine organizations support the infantry battalion through the actual attachment of supporting forces, in which case the battalion is reinforced, or through direct and/or indirect support. The discussion that follows will therefore be focused primarily on the infantry battalion. The discussion will work up the command chain to the point where communications enter the Defense Communication System (DCS). The reader familiar with Marine Corps organizations should be able to visualize similar communication systems in the combat support and logistic support organizations of the Marine Corps.

### A. VOICE COMMUNICATIONS

Secure voice communications over Very High Frequency (VHF) radio nets is the primary means of communications from the

battalion level on down. This method of communications extends organizationally as low as the rifle platoon, and when required can be extended down to the squad, fire-team, or individual Marine. VHF secure voice communications also extends from battalion up to the parent regiment. VHF and High Frequency (HF) radio nets provide the mobile command and control links required in a rapidly changing tactical environment. HF voice radio links are used to extend communications far beyond the range of the VHF radio capability. To handle the large volume of information exchange required between fixed battalion and regimental command post locations, an unsecured multichannel (multiplex) VHF radio link is also established. This four (and where necessary eight) channel trunk between battalion and regiment provides both dedicated staff-to-staff hot lines and common user channels terminated at the organizational tactical telephone switchboards. A similar system of VHF, HF and VHF Multiplex channels link the infantry regiment to the Marine division headquarters. At the Marine division headquarters AUTOVON access (either directly into the DCS or through a higher/lateral headquarters switchboard) may be available off the division switchboard. Thus, it is possible for a subscriber off a battalion switchboard to access the worldwide AUTOVON system by transiting the regimental and division switchboards.

At this time only the VHF radio nets are cryptographically secure. Previous discussion mentioned the PARKHILL cryptographic equipment that is presently being procured in limited

quantities to provide security for selected narrowband HF voice radio nets. The VHF narrowband multichannel circuits are unsecured voice links. The organization of the numerous radio nets and multichannel links are for the most part standardized for similar units, but special configurations can be established whenever the tactical situation so dictates.

## B. TELETYPEWRITER COMMUNICATIONS

Within each echelon of command from battalion on up there exists a record communications requirement. Factors that motivate the commander's desire to use an electrically transmitted record communication system are [Ref. 33]:

1. The sense of urgency and authenticity that an electrically transmitted message seems to have that a mailed message lacks.

> Most field commanders are reluctant to execute any order which has not been appropriately authenticated by his senior echelon of command and have, therefore, resorted to a record communications system to satisfy the implicit requirement for authenticity [Ref. 33].

The authenticity is created by the system's restricted access and message control procedures, and not from any particular human characteristic reflected on the transmitted document itself. A teletypewriter system cannot convey a signature or add the human touch of personal comments written by hand. However, such a personal touch can be conveyed exactly as intended by a facsimile transmission system.

2. The strict accountability required by the record communication system's operating procedures that provide a commander with recourse if the message is delivered late or not delivered at all.

3. The speed and security associated with an electrically transmitted document.

The present method of satisfying the electrical transmission of record communications in the Fleet Marine Force tactical environment is a system of 60 or 100 word-per-minute teletypewriter circuits. The system is designed to handle the record communication requirements of the battalion and higher level organizations. A teletypewriter link operating at one of the above speeds requires very little circuit bandwidth, making it possible to superimpose the teletypewriter signal onto one of the inter-organization multiplexed voice channels. Although it is possible to have a teletypewriter operator send messages directly from his keyboard to a receiving teletypewriter at another headquarters, it is seldom done due to the typing errors generated and/or the slow speed of most operaters. To remedy this problem a punched paper tape copy of the document to be transmitted is normally locally prepared in coded alpha-numeric/special character format by the operator on a tape reperforator machine prior to transmission. In a questionnaire (Appendix E) sent to the Communication-Electronics Office of various FMF headquarters organizations, one of the questions asked for the average time required to prepare the punched paper tape for an

average one page outgoing message. The reply's ranged from three to fifteen minutes, depending on the ability of the teletypewriter operator, with an average of about eight minutes. Once the punched paper tape is error free it is put into a tape transmitter connected directly to the teletypewriter circuit and sent out at the word-per-minute operating rate of the distant teletypewriter terminals(s).

For organizations at intermediate levels of command in a position to relay teletypewriter traffic, a tape reperforator unit connected to the incoming teletypewriter circuit reproduces a punched paper tape of the message as it is received. With this tape, retransmission of the message to the next higher level (or to any other terminal or relay point tied into that particular headquarters) is simply a matter of running the tape through the tape transmitter associated with the desired circuit path(s). At the division level the tape (if properly formated with the necessary header and ending information) can be entered directly into the DCS worldwide AUTODIN message system.

With few exceptions, all organizations in the FMF of battalion size or larger have various combinations and quantities of the teletypewriter equipment described above, depending on their particular mission requirements. For like organizations (T/O infantry battalions) the equipment list is the same and established by Table-of-Equipment allowances. In any major FMF command standard operating procedures are established for the internal organization of

the teletypewriter circuits. Just as for the voice nets/ circuits, the teletypewriter circuit structure can be modified as required to best satisfy the tactical need. The teletypewriter circuits are normally superimposed over the multiplexed VHF voice channels, when such links are available. However, for long range requirements HF radio can be employed to establish either netted or point-to-point teletypewriter links. For netted teletypewriter operations strict control over the subordinate terminals is required to maintain order on the net.

The teletypewriter system has some significant advantages and disadvantages which are listed below. Although some of the disadvantages were mentioned during the background discussion, they are summarized and should now be considered in the context of FMF requirements. The Marine Corps is also facing a teletypewriter availability problem which is the last disadvantage discussed.

1. Advantages

(a) Since the teletypewriter system is primarily superimposed on top of existing voice channels, additional radio frequency spectrum requirements, beyond those presently required for voice communications, are minimal.

(b) The punched paper tape prepared at the originating message terminal and regenerated at each relay echelon can be prepared in a format compatible with the DCS AUTODIN system. Thus, when the message is received at the AUTODIN entry

point (division headquarters for example) it can be entered directly into the AUTODIN system without preparation delays.

(c) The printing mechanism of a teletypewriter machine works on the principle of key impact. This process is compatible with the preparation of ditto masters. Therefore, the reproduction of inexpensive multiple copies is easily accomplished. At this time the capability of the teletypewriter to produce a ditto master is a significant advantage over facsimile devices that normally produce only a single copy. However, a new development that should enhance facsimile's application to record communications is an impact printing mechanism that may permit spirit masters to be produced from the facsimile for multiple copy reproduction [Ref. 33]. This feature is included on the AN/GXC-7A (a modified version of the original analog AN/GXC-7 with a digital tap for 2400 bps black and white service) for tests the Army is conducting. The TDF presently under deveopment will have the capability of reproducing "second generation" copies, from the "first generation" received copy, at the rate of ten to fifteen seconds per copy [Ref. 32]. This means that eight second generation copies could be reproduced in about two minutes. When using the TDF in this manner for reproduction purposes, it cannot receive incoming "first generation" documents. However, at the lower level units where traffic loads may not require continuous on-line operation, a single TDF might be able to satisfy both the communication and copy reproduction requirements.

2. Disadvantages

(a) The teletypewriter system is limited to alpha-numeric/special character representations. At this time hard-copy graphic documentation can only be exchanged between physically separated organizations via special courier or mail systems.

(b) Teletypewriter requires document preparation for transmission, which takes time. This results in a delay between receipt of an outgoing message at the transmitting terminal site and actual electrical transmission of the message. At the infantry battalion level, where the tactical situation can change rapidly, any delay in conveying vital information is a significant disadvantage.

(c) In any document preparation process, human errors are introduced. With the existing teletypewriter system each outgoing document is prepared twice. Even at the battalion level outgoing documents are typed once by a clerk for authorized command release, and a second time by the communication center teletypewriter operator when preparing the message on punched paper tape for electrical transmission.

(d) The present tactical teletypewriter equipment is old and unreliable. At operating speeds of 100 words-per-minute the standard tactical teletypewriter terminal, the AN/TGC-14A, experiences numerous failures. Even at the 60 WPM operating speed the mechanical failure rate is high. The author has personally experienced numerous failures of the AN/TGC-14A teletypewriter while participating in FMF Field operations.

> Although there have been numerous changes to the basic teletypewriter, such that the design is now very sophisticated, the teletypewriter still depends upon mechanical design which limits its reliability [Ref. 33].

Additionally, the teletypewriter with mechanical printing arms is a rather complex mechanical device that does not lend itself to modular replacement repair. This results in an unacceptably long time to repair down terminals and the requirement for specially trained maintenance personnel.

(e) A teletypewriter system requires specially trained operators at all levels where punched paper tapes are prepared or direct operator message entry is employed. The basic teletypewriter operator school at MCRD San Diego is 10 weeks long and emphasizes training in teletypewriter keyboard proficiency and operator procedures. A background in communication center operations is also included in this block of instruction.

(f) Teletypewriter availability in the FMF is becoming difficult.

At this time the Marine Corps is faced with a serious problem of providing a satisfactory tactical record communications capability in the late 70's and early 80's. The existing tactical teletypewriters (AN/TGC-14 & 14A) have almost reached the end of their useful life span and the source of support for this equipment (the Mite Corporation) has closed down its teleprinter division production lines. To compound this problem the AN/TGC-29 (a fully automatic send and receive teletypewriter with a paper tape reperforator/ transmitter, also manufactured by the Mite Corporation, was

procured for issue in 1972, but was never released to the Fleet Marine Force because of incomplete provisioning support [Ref. 33]. The present policy in the Second Marine Division is to only supply the infantry battalions with tactical teletypewriter equipment when they deploy in an independent status as a Battalion Landing Team [Ref. 34]. Although the complete rationale for this policy was not available, the author believes it can reaily be traced to two basic factors: non-availability of equipment and a lack of reliability when available. In a study of alternative solutions to the above problem many options were presented. The proposed options and the conclusions and recommendations are summarized in Appendix C. One of the options recommended the employment of the AN/GXC-7A facsimile for the battalion to regiment record communications link. Concerning this option, the study stated that:

> The capability of the facsimile to function as either a transmitter or receiver without extensive support equipment for message preparation makes this option highly effective in a communications center with low traffic loads [Ref. 33].

For purposes of employment doctrine development, the author believes that utilization of the AN/GXC-7A at the battalion to regiment level is highly desirable. The AN/GXC-7A is presently available in a durable version suitable for the field environment and weighs only 50 pounds. This option could not only be a temporary solution to the anticipated teletypewriter problem already discussed, but would also

provide valuable information on terminal/system employment doctrine based on actual utilization derived from requirements generated in field environments.

## C. SPECIAL COMMUNICATIONS

In addition to the voice and record teletypewriter systems described above, special data terminals are presently under development and testing for fire control and command information purposes. The data terminals are designed to transmit short digital bursts of highly formated specialized information over the tactical VHF radio nets. The bursts are of such short duration that little time is taken away from operator use of the radio nets on which the data terminals are operating. The data terminals will be located at the lower tactical levels and are designed to provide the field commander with a real time status on both the enemy and friendly situations.

With this general background on the existing FMF communication system, a discussion of digital facsimile employment alternatives follows.

## V. FACSIMILE EMPLOYMENT OPTIONS IN THE FMF

As with any tool, the best method of digital facsimile employment will ultimately be determined by the user. Any number of specific applications can be imagined, but to enumerate the many possibilities would be an endless unproductive effort beyond the scope of this paper. Actual hardware utilization will provide the information required to confirm obvious, and identify unique, employment applications. It is from such applications that specific hardware quantities and equipment configurations will be determined. The previously mentioned study, which is summarized in Appendix C, provided a suggested allocation of facsimile equipment if the facsimile option were adopted. A similar equipment breakdown, based on the study allocation, is provided by the author in Appendix D. The author believes the suggested allocation is only an initial estimate, because ultimate equipment requirements will be determined by the need of the users. The Marine Corps has leased 25 Model 603 3M Corporation commerical facsimile machines as an initial step toward facsimile doctrine development [Ref. 35]. These models should prove adequate for general doctrine development. However, since they are not designed for the rigors of a field environment, detailed doctrine development based on empirical data gathered in simulated or actual tactical environments is not possible. Interim reports from both the Second Marine Division and the

Second Marine Aircraft Wing [Refs. 36 & 37] indicate that excellent results were obtained in reducing writer-to-reader message delivery times using the Model 603 machines. The purpose of this discussion is to describe three general employment options from which any number of specific hardware applications should readily be visualized by the reader.

## A. STAFF APPLICATIONS

Every tactical organization in the Marine Corps of battalion/squadron size or larger has a formalized staff to support the commanding officer. Both the operational and administrative details needed to sustain the operations of any organization justifying a formal staff requires the generation and exchange of information through the vertical chain-of-command and also across horizontal lines with adjacent and supporting units. In the Marine Corps the preponderence of tactical information is exchanged between division/regiment/battalion Combat Operation Centers (COC) and associated operations and intelligence staff sections. Although much coordination is accomplished orally, the detailed review of tentative plans, schedules, proposals, etc. can best be accomplished by the written word or graphic representation. A staff can support the commander most effectively if information is readily available. This is especially true in today's rapidly changing tactical environments. To be effective the staff of any organization must have access to an effective Management Information System (MIS). The MIS should operate on as close

to a real-time basis as possible. Yet, in the FMF today there is no real-time system for the inter-staff exchange of alpha-numeric/graphic documentation. In a large command headquarters complex, with widely dispursed staff locations an intra-staff MIS document exchange capability may also be desirable.

In the civilian environment and at the higher DOD levels, facsimile exchange via the public telephone system is proving to be an invaluable asset. While working as a member of the OPNAV staff in the Pentagon, the author utilized a commercial analog facsimile device to exchange information within the Washington D. C. area. The facsimile was used over the regular telephone system and also over the secure AUTOSEVOCOM telephone system. The capability proved invaluable for the rapid exchange of time critical information in any format. The MIS message exchange requirements of the F-15 development program were satisfied by a secure high-speed digital facsimile system. The system utilized government furnished crypto equipment and operated over unconditioned telephone circuits using a 2400/4800 bit rate modem. It was stated that "the managerial value of the system has been incalculable"[Ref. 38]. In the Marine Corps the real-time exchange of hard-copy documentation between staffs, Combat Operation Centers and Fire Support Coordination Centers, to cite a few possible user applications, could greatly enhance a command's operating efficiency. Current technology digital facsimile equipment designed for the tactical environment

operating over dedicated (hot line) or switched telephone channels could provide an improved MIS capability through the informal rapid exchange of "hard-copy" documentation between all staff echelons. The U. S. Army is studying the employment of facsimile in the tactical environment and anticipates employing the devices in switched and point-to-point configurations within the division down to and including battalion headquarters.

> A type intradivisional TDF system utilizing the existing divisional multichannel system will consist of TDF terminals (record transceivers and cryptographic equipment) employed at selected locations interconnected through the divisional switched communication system [Ref. 16].

B. AUGMENTATION OF FORMAL RECORD COMMUNICATIONS

Today's record communication system is limited to alpha-numeric/special character formats. To quote the old axiom that "a picture is worth a thousand words" may be helpful in explaining this employment option. If a picture can better explain an idea than words, the transmission of a formal message containing whatever diagrams are required to help convey the intended meaning should be a highly desired capability. With an unlimited format capability the mix between alpha-numeric and graphic information contained on the message would be determined by the needs of the drafter. For official messages containing graphic information, a digital facsimile system could be utilized to augment the existing teletypewriter system. Messages containing both written and graphic information could be transmitted entirely

over a supporting facsimile system or split up under the same message date-time-group identifier. The written word could be transmitted over the teletypewriter system and the graphic information could be sent over the facsimile system. Depending on the graphic traffic volume, switched or dedicated facsimile circuits would be employed. High volume graphic traffic would require dedicated circuits. Dial-up common user voice channels could be employed for low volume requirements. Such employment would eliminate the limitation that messages transmitted electrically be restricted to an alpha-numeric/special character format. Additionally, since digital facsimile has proven to be compatible with the AUTODIN system, it should be possible in the not to distant future for messages containing graphic information to be transmitted from the tactical environment directly into the world-wide AUTODIN system.

C. REPLACEMENT FOR TELETYPEWRITER

Since a digital facsimile will transmit graphic information in any format, and alpha-numerics can be considered a form of graphic representation, it would appear that a facsimile system could effectively replace a teletypewriter system. Recent developments in data compression, LSI/MOS components and modem technology have made this concept feasible. Yet, just a few years ago, when analog facsimile was the technological state-of-the-art, this concept, although considered, was not viable [Ref. 3]. If formal record communications at the

tactical levels can be transmitted with little or no preparation delay by Marines without special teletypewriter training, the advantages of reduced response times and specialized manpower savings are obvious. This final employment option is the concept that would have the most singificant impact on future Marine Corps tactical record communications systems and operating procedures. However, the concept is feasible. In the MCDEC study of the teletypewriter problem that the Marine Corps is now facing it was stated that:

> With increased resolution and reduced transmission time, the facsimile becomes a viable candidate for providing record communications within the tactical environment as a replacement for the teletypewriter [Ref. 33].

In a query by the CNO to the Fleet Commanders concerning the Navy's requirement for the TDF, the response by CINCUSNAVEUR stated that:

> The proposed lightweight tactical digital facsimile (TDF) equipment promises to reduce the communications equipment required in support of tactically deployed amphibious units and landing parties (which are presently equipped for multichannel operations). The TDF could serve all record communications needs of these units obviating the necessity for teleprinter equipment and associated terminal equipment.... on afloat units, the TDF could provide the means to separate the important Command Control Communications ($C^3$) data from the administrative, logistic and personnel messages. The $C^3$ data could be directly exchanged between the FSCC and $C^3$ centers ashore and afloat $C^3$ operational areas [Ref. 39].

The author believes the three general employment options presented encompass the wide range of specific employment applications that will ultimately be developed. The final section of this thesis outlines a broad concept of tactical digital facsimile employment in the FMF.

## VI. PROPOSED FMF DIGITAL FACSIMILE EMPLOYMENT CONCEPT

In order to effectively employ digital facsimile, the broad concept of employment in the FMF proposed by the author would incorporate all three of the general application options outlined in the preceding chapter. The discussion of the broad concept addresses replacement of teletypewriter, augmentation of teletypewriter, and staff applications (in that order) at the various command levels. The last section of the chapter will delineate the significant advantages and disadvantages of the proposed concept.

### A. REPLACEMENT OF TELETYPEWRITER

In order to eliminate message preparation delays and format restrictions at the operational levels (battalion and regimental size organizations), digital facsimile operating over dedicated nominal 3 KHz VHF multiplexed circuits can be employed for inter communication center links. Such a system could replace the existing tactical teletypewriter network below the AUTODIN entry level. Current digital facsimile technology employing digital data compression and adaptive modem equalization can provide a record communication system with the capability of exchanging information in any format. Operating at transmission speeds of less than a page-per-minute for 100 lpi resolution, the information throughput of a digital facsimile system meets or exceeds the throughput

capability of 100 word-per-minute teletypewriter systems. The author believes digital facsimile could replace all teletypewriters below the AUTODIN entry level, however, the MCDEC study on the teletypewriter problem suggested the following:

> The prime candidates for using facsimile for record communications within the Marine Corps would be the mobile combatant who does not have a heavy traffic load, the infantry battalion [Ref. 33].

The author concurs that the infantry battalion is a likely candidate for facsimile employment, but would like to emphasize the fact that at operating speeds of one minute or less per standard page, digital facsimile operating over a nominal 3 KHZ channel is capable of handling traffic loads as heavy as a 60 or 100 word-per-minute teletypewriter terminal superimposed over the same nominal 3 KHz voice channel. In an after exercise evaluation of secure facsimile in support of a joint task force exercise, the United States Readiness Command commented that:

> The facsimile network adds a communication dimension that potentially could replace message traffic (teletype) at the tactical level in addition to providing direct interface into the existing AUTODIN network via Optical Character Reader entry points or by the use of magnetic tape [Ref. 40].

In the case of a reinforced division, the division headquarters communication center is the likely AUTODIN entry point for all traffic generated by subordinate units and the division headquarters staff. A data communications terminal, AN/TYC-5, is presently in production that will provide a

direct digital data interface for MAF/Division/Wing size units into AUTODIN switching centers and/or Naval Communication Stations [Ref. 41]. Facsimile documents, like teletypewriter messages, would be sent either directly or via an intermediate communication facility to the Division headquarters communication center. The number of times successive generations of a "hard-copy" facsimile communication can be re-entered into a facsimile transmission system is limited. The number of possible retransmissions is dependent on the quality of the received copy. The author could find nothing in the way of a study in this area. However, while visiting the Dacom Corporation in Santa Clara, California the author conducted an experiment to observe the effects on document quality from the retransmission of successive generations of received digital facsimile documents. The experiment employed two Dacom 430 digital facsimile terminals operating through a local commercial (dial-up) telephone system. Operating at the 100 lpi setting a fifth generation copy (five successive retransmissions of received copies) of a standard size font typewritten letter was readable. Operating at 200 lpi the seventh generation of the same document was readable.

If digital facsimile terminals used for retransmission are equipped with an off-line buffer that can store-and-forward the actual digital signal, the number of retransmissions of a particular document would be unlimited. For instance, instead of positioning punched paper tape reperforators/transmitters at intermediate relay locations as is

presently done, a digital store-and-forward device could be employed to accomplish the relaying duties. The store-and-forward device would only need sufficient storage for one or two messages and could use an internal (memory core) or external (magnetic tape) capability. Dacom Corporation has conducted experiments using a standard tape cassette as the store-and-forward medium and found the cassette to be satisfactory for this purpose [Ref. 23].

> Typically, a 7" reel of audio tape can store 700-800 pages of compressed facsimile data. Retransmission of facsimile copy from tape is free from 'second-generation' degradation [Ref. 42].

The technology for the above capability is available today. Additionally, many messages generated within a Marine division are for internal addressees and are never sent outside the division. For these messages no manual punched paper tape preparation for AUTODIN entry would be required, resulting in a significant teletypewriter operator manpower savings. The previously mentioned questionnaire (Appendix E) asked what percentage of messages generated in an operational environment at battalion/regiment level required entry into the AUTODIN system. The answer ranged from 20% to 60%. Even if 50% of all messages generated required AUTODIN entry, the manpower savings resulting from not preparing punched paper tape on the other 50% would be significant.

For those messages that require AUTODIN entry, the punched paper tape of the message could be prepared at the division communication center where conditions more suitable

to message preparation normally exist. A pool of teletypewriter operators tailored to the outgoing message traffic volume requirements could be employed to prepare the AUTODIN entry tapes. This approach would allow for more effective utilization of skilled teletypewriter personnel.

A more sophisticated approach than manual punched tape preparation would be to utilize an Optical Character Reader (OCR) device to scan the outgoing message, converting the alpha-numeric characters on the facsimile document into either an ASCII coded punched paper tape copy, or directly entering the generated ASCII codes into the AUTODIN system. In the OPNAV communication center located in the Pentagon, and at NAVCOMPARS configured NAVCOMSTAS, and OCR device is being used to read formatted outgoing messages directly into the AUTODIN system. The Marine Corps is presently developing an Automated Message Entry System (AMES) for use in conjunction with the AN/TYC-5 high speed data communication terminal. AMES will include an OCR device that will allow the direct entry of properly formatted typed messages into the AUTODIN system.

> The AMES will allow an operator to process messages for transmission while significantly reducing overhead time as compared to current manual processing [Ref. 43].

With a standard operating procedure requiring that, whenever possible, subordinate commands and division staff officers must prepare messages for AUTODIN entry in a specified format using block or typewritten characters suitable for OCR

interpretation, the employment of OCR devices for the conversion of a formatted facsimile document (prepared with a suitable character font) to ASCII codes on punched paper tape or direct AUTODIN entry is entirely feasible. Additionally, if the outgoing document contained both character and graphic representations it could be transmitted via the AUTODIN system in its basic facsimile bit stream configuration by simply adding the proper message header and ending information. This capability has already been demonstrated in the previously discussed tests conducted by the Defense Communication Agency.

In the past, there was little need for the battalion or regiment to originate traffic into the worldwide AUTODIN system without first clearing such traffic with the parent division. However, the Marine Corps Development and Education Command believes that there is a trend toward more decentralized input of data into the worldwide AUTODIN system [Ref. 33]. OCR conversion for autodin entry of formatted messages such as MMS, JUMPS, 3M and MARES can readily be accomplished from documents transmitted via a facsimile communication system from lower echelon commands.

> The battalion is required to prepare current MMS forms in optical Character Readable format now for inclusion in the worldwide MMS data base [Ref. 33].

If the proposed concept were implemented, a combination of both manual punched paper tape and OCR tape preparation/ direct entry would appear to be the most likely message

preparation procedure for those messages requiring AUTODIN entry. It is unlikely that any hastily prepared handwritten message from lower level tactical units would be suitable for OCR intrepretation, yet, in a tactical situation such a message may require AUTODIN entry.

B. AUGMENTATION OF TELETYPEWRITER

At the higher command levels, where the message traffic volume is heavy, digital facsimile can be utilized to augment the teletypewriter system. In a Marine Amphibous Force (MAF) composed of one or more divisions, aircraft wings, and logistic support organizations, along with a MAF headquarters staff, the heavy volume of message traffic exchanged over relatively long distances (when compared to VHF radio ranges) will require full time high-speed teletypewriter links. However, since there are normally several voice channels between such organizations, one or more dedicated facsimile channels paralleling the teletypewriter circuit(s) could readily be established. With parallel teletypewriter and facsimile transmission links between communication centers, formal record communications would not be restricted to the alpha-numeric/special character format. An additional advantage would be the alternate record communication link that would be available if a teletypewriter terminal or circuit path went down.

C. STAFF APPLICATIONS

As an informal tool for inter and/or intra staff coordination the digital facsimile could be utilized at all levels. At the lower echelons, where staffs are smaller, a digital facsimile transceiver could be employed on a shared basis. In an infantry battalion it is likely that the S-3/COC would have the greatest requirement for hard-copy inter-staff document exchange. Facsimile devices could be placed in the Combat Operations Center for the exchange of high priority operations traffic such as overlays, photos, and written operations plans. During the previously mentioned readiness command exercise the secure digital facsimile terminals were intentionally located in operations centers.

> The purpose of locating the terminals in this manner was to insure immediate operations center to operations center communications over the network. Intentionally, administrative controls were not established except for a test data collection form to insure users were not encumbered with controls currently required of record message traffic [Ref. 40].

At the lower level organizations a single facsimile device could be made available to all staff sections that require an informal facsimile communication capability. At the division headquarters level the G-3 might require a facsimile capability full time, while the G-1 may need a facsimile infrequently. In the above case a combination of dedicated and shared facsimile device utilization would be appropriate. The mix of facsimile transceivers needed for staff utilization will be determined as the devices are utilized and their

capability realized. Since digital facsimile will operate over the switched telephone system or existing dedicated circuits, no additional communications capability is required and the subscriber population would only be limited to digital facsimile terminal and telephone availability.

## D. ADVANTAGES OF PROPOSED CONCEPT

The proposed digital facsimile concept of employment would provide the following advantages over the existing FMF record communication system:

1. The capability of exchanging hard copy graphic information both formally via the communication center network and informally via telephone (switched common user and dedicated channels).

2. Faster writer to reader response time for formal messages because of the elimination of communication center message preparation requirements at organizations below the AUTODIN entry level.

3. The elimination of human errors previously introduced in the transmission preparation process and a reduction of errors caused by electrical interference.

4. The elimination of message preparation (punched paper tape) for internal messages that do not require AUTODIN entry.

5. The elimination of teletypewriter operators skilled in punched paper tape preparation in organizations below the AUTODIN entry point.

E. DISADVANTAGES OF PROPOSED CONCEPT

1. The utilization of a full voice channel for record communications instead of superimposing the record communication system on top of existing voice channels.

2. The lack of a direct spirit master ditto mat preparation capability for message reproduction purposes. There are alternate means available for producing additional copies or a spirit master from a black and white document, however, an impact printing method of document reception appears to be the most desired solution at this time.

3. There are a limited number of successive retransmissions possible from a received "hard-copy" facsimile transmission before copy quality degrades below an acceptable level. However, if a system of data store-and-forward were incorporated into the equipment employed at the relay locations, the number of retransmissions would be virtually unlimited.

## VII. CONCLUSIONS

(a) Major technological advances have occurred in facsimile communications in the last five years.

(b) Digital facsimile communication systems have significant advantages over analog facsimile systems.

(c) Digital facsimile will be compatible with the future DOD trend toward an all digital communication system. This point is very important because for any new equipment employment concept to be viable, it must satisfy this requirement.

(d) Many of the limitations that rendered the AN/GXC-7 analog facsimile unsuitable for FMF use have been overcome with recent facsimile technology.

(e) The Marine Corps is presently faced with a serious problem of providing adequate record communications to lower level FMF units in the latter 1970 and early 1980 time frame.

(f) The tactical digital facsimile (TDF) should be available in production quantities in the early 1980 time frame.

## VIII. RECOMMENDATIONS

(a) That the Marine Corps take steps to acquire a sufficient quantity of currently available facsimile devices for tactical doctrine development purposes. The devices should be suitable for employment in the field. At this time it appears that the AN/GXC-7A is the only readily available facsimile device designed for the field environment.

(b) That the TRI-TAC Tactical Digital Facsimile (TDF) program be monitored closely to insure that the future digital facsimile requirements of the Marine Corps are incorporated in the production version of the TDF.

(c) That the applicability of tape cassettes as an intermediate store-and-forward device for the inter organization relay of facsimile documents below the AUTODIN entry level be investigated.

(d) That the resolution quality of first and subsequent generations of received facsimile documents be investigated to determine the copy quality required for formatted OCR interpretation.

(e) That the problem of multiple copy reproduction be investigated in depth, taking into consideration the off-line internal "second generation" reproduction capability of the TDF as a possible alternative approach at the battalion/regimental organizational levels.

## APPENDIX A

## (EXAMPLES OF TACTICAL FACSIMILE DOCUMENT APPLICATIONS)

The following page, which gives a few examples of documentation suitable for facsimile transmission, is an actual "first generation" facsimile of the original document. This "first generation" copy was obtained by transmitting the original document from one Dacom 430 digital facsimile terminal, through a local commercial telephone exchange, to another Dacom 430 terminal. The copy quality (100 lpi horizontal by 200 lpi vertical) is representative of the copy quality that can be expected from current digital facsimile technology. This copy took less than one minute to transmit.

APPENDIX A (Examples of tactical facsimile applications)

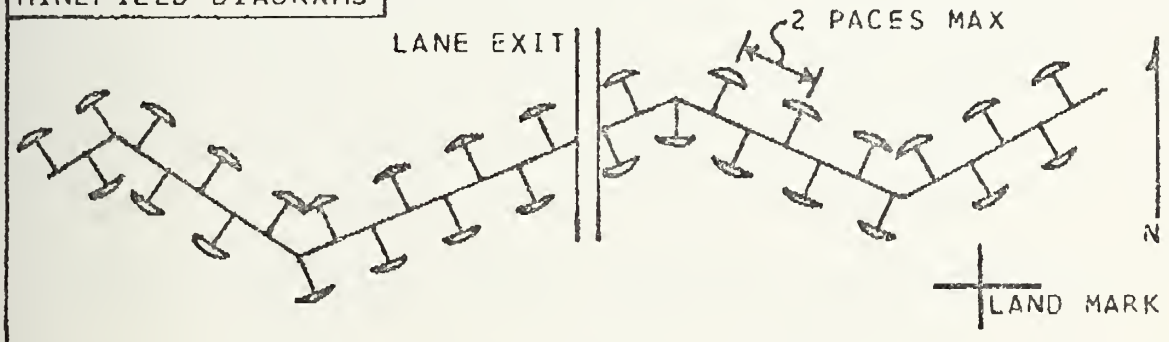
TYPED MESSAGES

P300800Z MAR 75
FM AUTHUR
TO READER
UNCLAS
FACSIMILE COMMUNICATION
A. THIS STUDY
1. AS OUTLINED IN REF A THE
ADVANTAGES OF FAX ARE MANY.

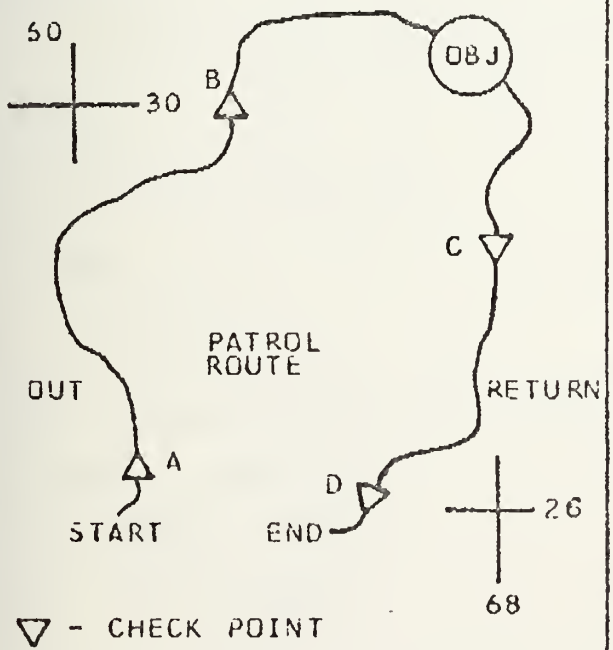
HANDWRITTEN MESSAGES

BT
P301800Z
FM BOXCAR ONE
TO BOXCAR
REQ SUPPORT OF FAX COMM
DURING NEXT EXERCISE.
BT K. D. Johnson

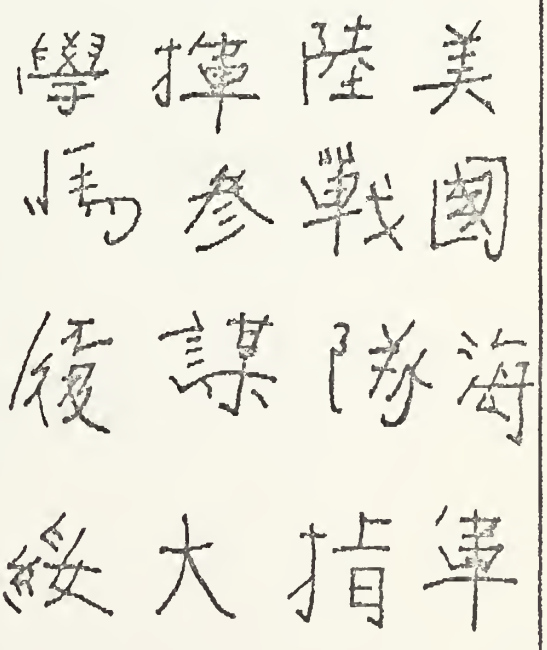
MINEFIELD DIAGRAMS




OVERLAYS




INTELLIGENCE DATA



## APPENDIX B

## (TACTICAL DIGITAL FACSIMILE (TDF) CHARACTERISTICS)

The major specification characteristics listed below were extracted from the TDF Technical Development Plan [Ref. 28].

* Small lightweight equipment
  - Transmitter (Scanner) 2.5 cu. ft., 50 lb. max.
  - Receiver (Recorder) 3.5 cu. ft., 50 lb. max.
  - Transmitter and Receiver 6 cu. ft., 80 lb. max.
* Low Resolution, 1:1 aspect, 100, 150, 200 pel/in.
* 2 (Black-and-white), 4, 8, 16 or 32 gray shades
* Opaque or transparent copy, 9 in. X 36 in. max.
* Digital signaling, COMSEC compatible, selectable data rates of 2.4, 4.8, 9.6, 16, and 32 kbs
* Receives meteorological transmissions in 1/2 scale
* Redundance reduced through data compression
  - Black-and-white compression = 5.4:1
  - Gray scale compression = 3:1
* Compatible with fixed, land mobile, ship, and aircraft platforms
* Impervious to harsh environments
  - Salt fog
  - Blowing sand, dust
  - Immersion (when in carrying case)
* High availability
  - MTBF = 2500 hr.
  - MTTR = 30 min.
  - Ai = 0.9998

## APPENDIX C

### (SUMMARY OF MCDEC STUDY OF RECORD COMMUNICATION ALTERNATIVES)

The information provided below was extracted from CG MCDEC letter D 101/BBB:SF 2010 [Ref. 33] to CMC dated 31 Jan 1975.

| OPTION | SUMMARY DESCRIPTION |
|---|---|
| I | Rehabilitation and continued support of the AN/TGC-14A(V) and the AN/TGC-29(V) teletypewriter. |
| II | Continued degraded operations with the AN/TGC-14A(V) and AN/TGC-29(V) and use of fixed plant teletypewriters at regiment and above. |
| III | Use of Army Forward Area Teletypewriter (FATT). |
| IV | Use of the TRACOR AN/TGC-44 as a replacement for the AN/TGC-29(V). |
| V | Use of Facimile AN/GXC-7A as a replacement for teletypewriters on the regiment to battalion link. |

Options I, II and III were proposed as complete solutions, while options IV and V are partial solutions that would have to be combined with some other alternative to become a complete solution. No clear cut course of action could be identified from the alternatives and the recommended course of action encompasses portions of several of the options.

RECOMMENDED COURSE OF ACTION

(a) Immediate release of the AN/TGC-29(V) from depots.

(b) Contractor support of the AN/TGC-14A(V) and AN/TGC-29 (V) through 1982.

(c) Continued support of the AN/TGC-44 program.

(d) Use of fixed plant teletype equipments in limited amounts at Division, Wing and MAF headquarters.

(e) Increased effort and coordination with TRI-TAC to insure that the Composition and Editing Device (COED) is a viable solution to the Marine Corps record communications problem.

## AUTHOR'S COMMENT

The author concurs with recommended courses of action (a) and (b), and with the "increased effort and coordination with TRI-TAC" portion of (e) above. However, in view of the TRI-TAC Tactical Digital Facsimile (TDF) development presently underway by the Navy, consideration should be given to the TDF as a possible record communication option below the AUTODIN entry level. The TDF is expected to go into production in the early 1980 time frame. The arguments presented in the body of the thesis support this option.

## APPENDIX D

## (SUGGESTED INITIAL FACSIMILE EQUIPMENT ALLOCATION)

| T/E No. | Organization | No./Org | Total |
|---|---|---|---|
| 1038 | Inf Bn | 2 | 54 |
| 1096 | HqCo, Inf Regt | 4 | 36 |
| 1128 | D/S Bn | 2 | 18 |
| 1148 | G/S Bn | 2 | 6 |
| 1196 | HqBtry Arty Regt | 4 | 12 |
| 1378 | Eng Bn | 2 | 6 |
| 1428 | Recon Bn | 2 | 6 |
| 1757 | H&S Serv Bn | 2 | 6 |
| 1868 | Shore Party Bn | 2 | 6 |
| 1883 | Comm Co Hq Bn | 6 | 18 |
| 3443 | Comm Co FSR | 6 | 18 |
| 4226 | FAG | 4 | 12 |
| 4737 | H&S Co Rad Bn | 2 | 4 |
| 4836 | Comm Spt Comm Bn | 8 | 24 |
| 4883 | Comm Co Comm Bn | 8 | 24 |
| 8612 | MWCS | 6 | 18 |
| 8631 | MACS | 2 | 6 |
| 8640 | MASS | 2 | 6 |
| 8710 | MWSG | 2 | 6 |
| 8820 | MABS (MAG) | 2 | 6 |
| 8920 | MABS (H) | 2 | 6 |
| | Total for Three MAF's | | 298 |
| | Training 20% | | 60 |
| | Replacements 20% | | 60 |
| | Total | | 418 |

TABLE II

## APPENDIX E

(QUESTIONNAIRE SENT TO SELECT FMF ORGANIZATIONS)

The questionnaire on the following page was sent to the communication-electronics office of the Second Marine Division, Third Marine Aircraft Wing, and the III Marine Amphibious Force headquarters. More than one value indicates the high and low limits of the responses.

THESIS QUESTIONNAIRE # 1 (Fax communication in the FMF)

Return to: Major K. D. Johnson USMC
USN Postgraduate School
SMC # 2858
Monterey, California 93940

Organization/Point-of-contact queried: III Marine Amphibious F. 2nd Marine Division 3rd Marine Aircraft Wing

Q1. What is the average time required to prepare the teletype transmission tape for an average one page outgoing message? (An estimate provided by experienced communication center personnel would be fine.)

Ans. 3-15 minutes

Q2. Of the messages generated in an operational environment at the Battalion/Regiment and Squadron/Group level, what percentage require transmission beyond (entry into AUTODIN or relay to higher HQ such as MAF) the parent Division and Wing Headquarters? (If emperical data is not available a best estimate from personnel with current experience will suffice.)

Ans.

| | % msgs requiring trans beyond Div/Wing HQ. | Types of msgs requiring external transmission |
|---|---|---|
| Battalion - | 8-60% | Supply, CMD & COORD of equip., Operational |
| Regiment - | 20-60% | Supply, Maint., Repair Parts RQMTS, Operational |
| Squadron - | 85-90% | Supply, Quotas, Re-enlist orders, Maint., Safety, Other admin. |
| Group - | 90-95% | Supply, Maint., Flight Frags, Safety, A/C Readiness |

COMMENTS:

Q3. How many school trained personnel are required (T/O and Manning Level) for teletype requirements at the below organization levels?

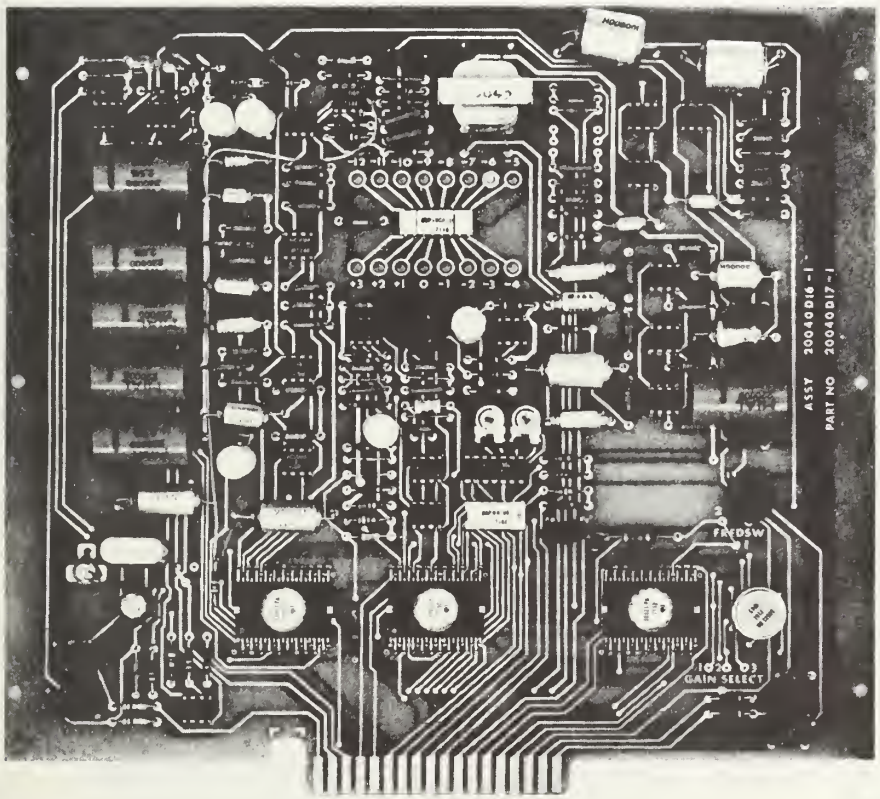
Ans.

| | T/O | Manning Level |
|---|---|---|
| Battalion - | 4 | 3 |
| Regiment - | 11/12 | 9/10 |
| Squadron (if none omit) | N/A | N/A |
| Group - | 12 | 9 |

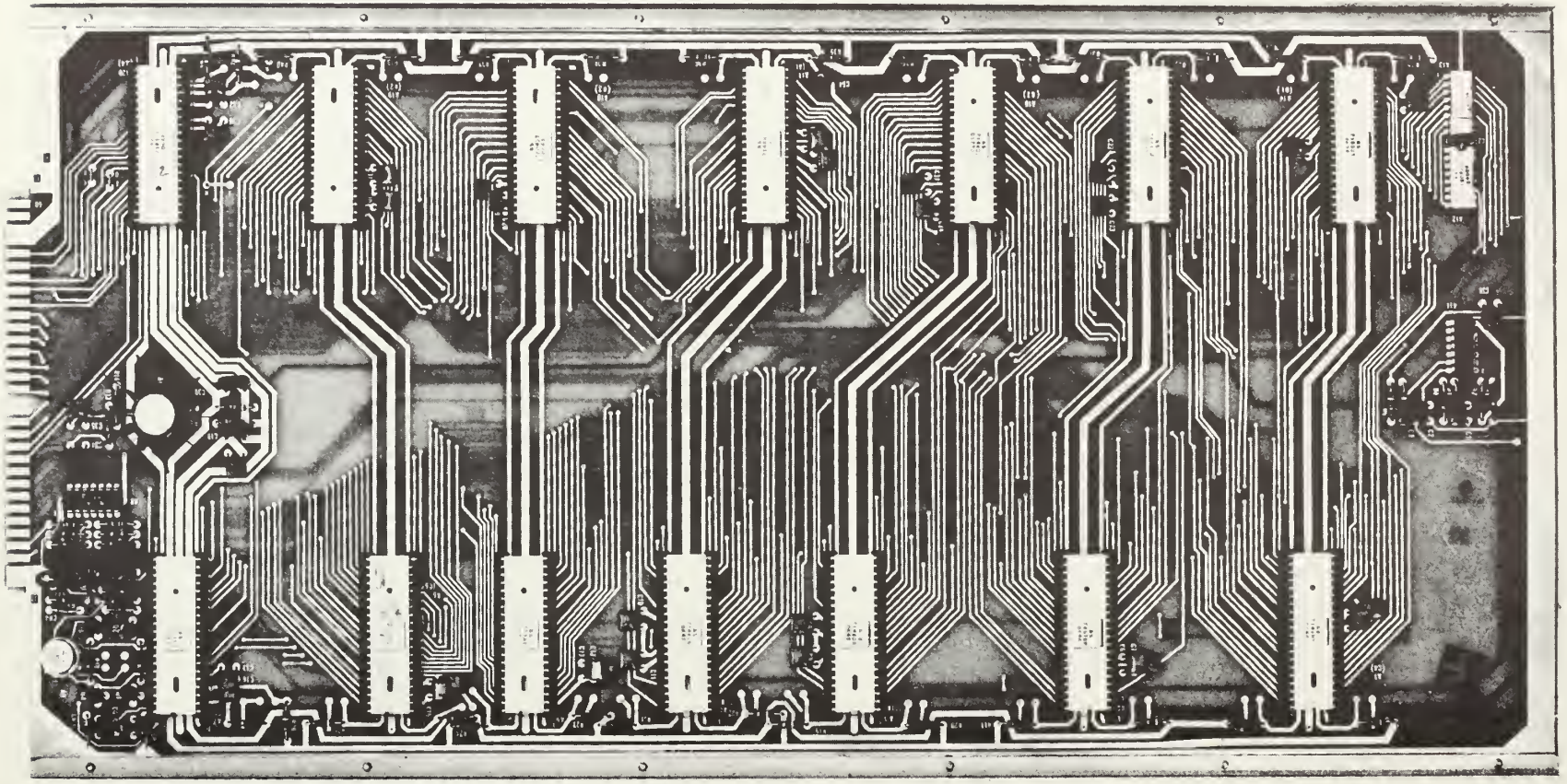
## APPENDIX F

## (EXAMPLES OF DIGITAL FACSIMILE LSI/MOS TECHNOLOGY)

The photographs on the following two pages are of a modem printed circuit board and a data compression printed circuit board (DFC-20) respectively. These printed circuit boards are utilized in the Dacom 412 digital facsimile terminal and reflect current production technology.




Modem Printed Circuit Board



DFC-20 Printed Circuit Board

## APPENDIX G

## (GLOSSARY OF ACRONYMS AND DEFINITIONS)

The sources of those acronyms and definitions taken directly from published documents are identified by a suffix number. The sources with their respective suffixes are provided below.

1. Introduction to Teleprocessing, James Martin, Prentice-Hall, 1972.

2. Teleprocessing Network Organization, James Martin Prentice-Hall, 1970.

3. JCS Pub. 1.

## GLOSSARY OF ACRONYMS AND DEFINITIONS

Analog Transmission - The communication of a continuously variable signal as opposed to a discreetly variable signal. Physical quantities such as temperature are continuously variable and so are described as "analog." Data characters, on the other hand, are coded in discrete separate pulses or signal levels, and are referred to as "digital" [1].

ASCII - American Standard Code for Information Interchange. An eight-level code for data transfer adopted by the American Standards Association to achieve compatibility between data devices [1].

AUTODIN - Automatic Digital Network. The store-and-forward teletypewriter switching subsystem of the world-wide Defense Communications System consisting of computer controlled automatic switching centers serving the DOD community of teletypewriter subscriber terminals.

AUTOSEVOCOM - Automatic Secure Voice Communication Network. A world-wide, switched, secure voice network developed to fulfill department of defense long haul secure voice requirements [3].

AUTOVON - Automatic Voice Network. The principal long-haul, unsecure voice communications network within the Defense Communications System [3].

Battalion Landing Team (BLT) - In an amphibious operation, an infantry battalion normally reinforced by necessary combat and service elements; the basic unit for planning an assault landing [3].

Circuit Switching - or "Line Switching" is a switching system wherein a circuit path is physically established between the communicating terminals. In contrast, Message Switching, which employs a store-and-forward process, has no physical path established between the communicating terminals [2].

Digital Transmission - A discrete or discontinuous signal; one whose various states are discrete intervals apart [1].

First Generation - The term used in facsimile communication to identify the first transmission copy generated from the original document. Subsequent generations refer to copies received from the retransmission of a previous generation copy. For example, a "second generation" copy would be the copy received from the transmission of the "first generation" copy.

Frag. Order - Fragmentary Order. An abbreviated form of an operation order, usually issued on a day-to-day basis which eliminates the need for restating information contained in a basic operation order. It may be issued in sections [3].

JUMPS - Joint Uniform Military Pay System.

MARES - Marine Automated Readiness Evaluation System.

Message Switching - The technique of receiving a message, storing it until the proper outgoing line is available, and then retransmitting it. No direct connection between the incoming and outgoing terminal lines is set up as in circuit switching [1].

Modem - A contraction of "modulator-demodulator." Modulation is the process by which some characteristic of one wave is varied in accordance with another wave or signal. A modem is required to make discrete digital signals compatible with communication lines designed for continuous analog transmission [1].

MMS - Manpower Management System.

Narrowband - A term used to describe a voice communication channel 3000 Hz or less in bandwidth.

NAVCOMMSTA - Naval Communication Station.

NAVCOMPARS - Naval Communications Processing and Routing System.

Optical Character Reader (OCR) - In communication terminology an electronic scanning device designed to read alpha-numeric characters and convert the particular character into an appropriate code (such as ASCII) for transmission over a communication system. The alpha-numeric characters must normally be formatted in a specified font for proper interpretation.

Real Time - An information system that receives and transmits data sufficiently quickly to affect the functioning of the decision making environment it supports [2].

Resolution - A term used in reference to the quality of a facsimile transmission copy. Resolution is usally expressed in terms of the number of vertical and horizontal scan samples that are taken of the original document in order to faithfully produce the facsimile copy at the receiving terminal.

Store-and-Forward - A term used in "hard-copy" message transmission where intermediate relay stations receive and hold a message until the proper communication channel becomes available and the message can be forwarded either to its destination or another relay station farther down the line.

3M - Naval Aviation Maintenance and Material Management System [OPNAV Instruction 5442.2D, 31 August 1973].

LIST OF REFERENCES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